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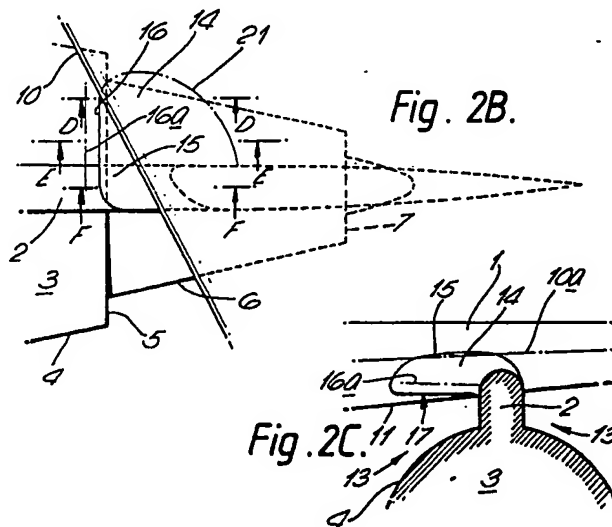
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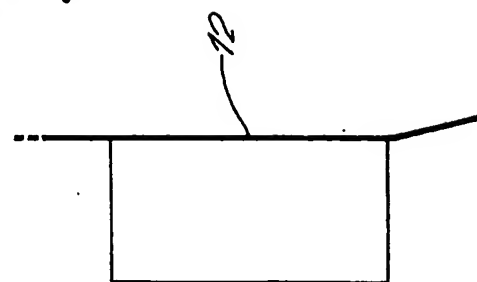
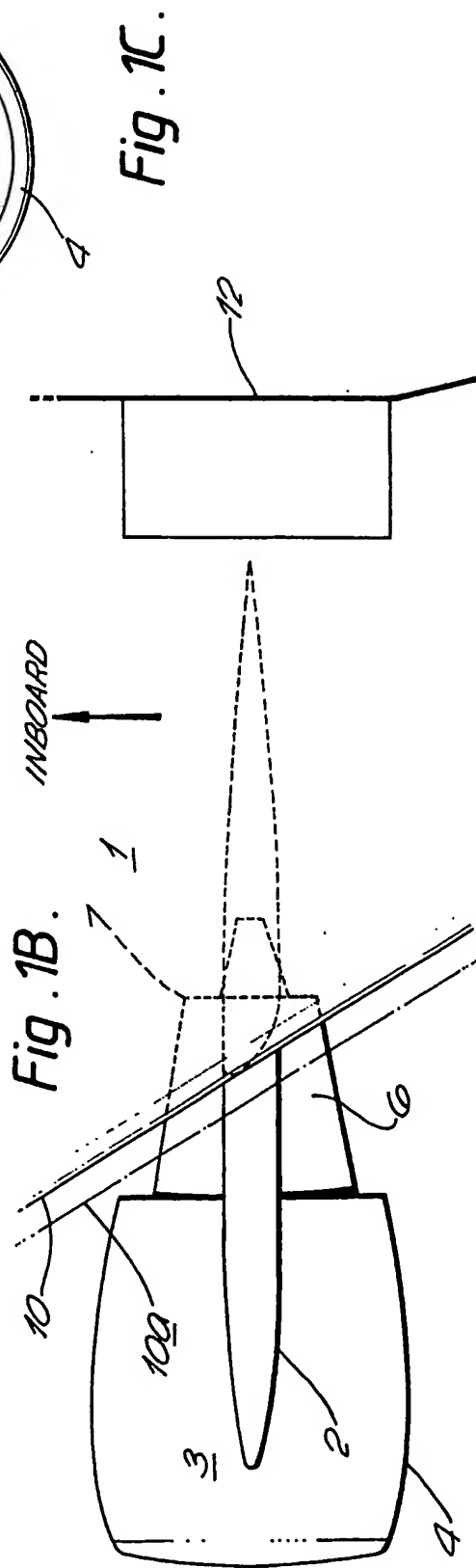
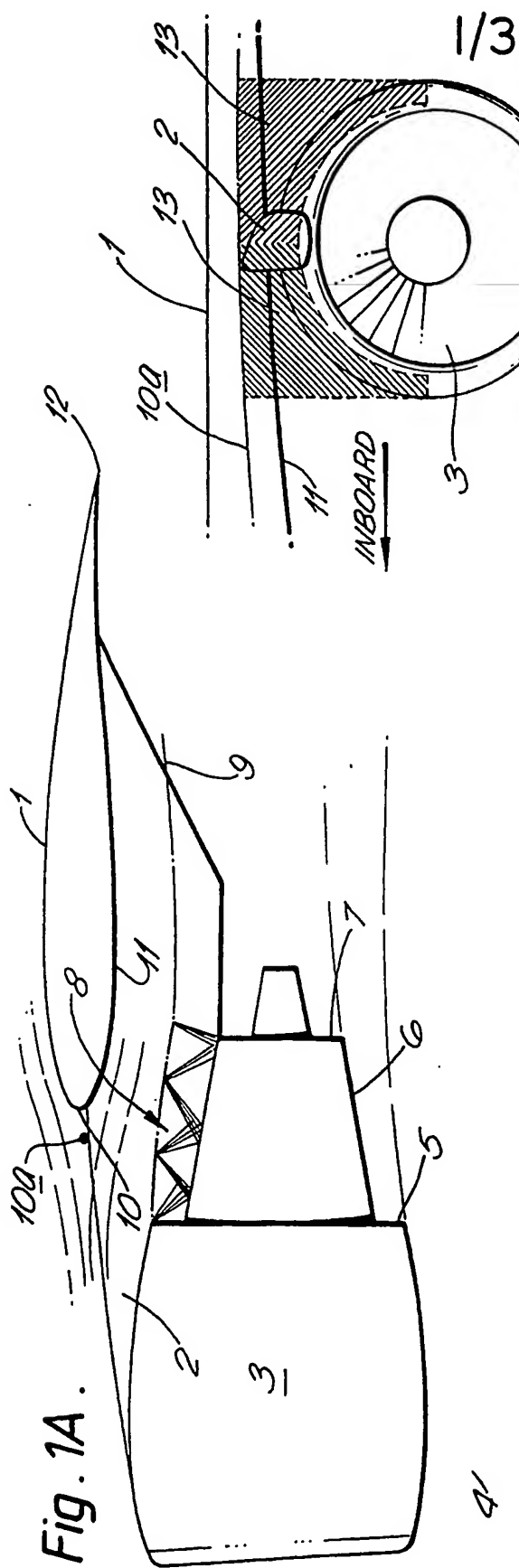
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## (54) Underwing engine installation for aircraft

(57) An aircraft having a wing 1, a nacelle 3 housing a jet propulsion engine the efflux from which extends aft of the nacelle, and a pylon 2 depending from the wing carrying the nacelle, an undersurface region of the wing, a side surface region 11 of the pylon, and an upper surface region 4 of the nacelle and/or any efflux therefrom together forming a channel into which air from the free airstream is urged from a capture area bounded in part by stagnation lines formed by said wing, pylon, and nacelle, the wing having, in the region of the channel, contour modifying means 15 which form a new stagnation line positioned such that said capture area is reduced and a revised wing undersurface region is produced within the channel with little or no chordwise curvature. The means 15 may include a slot (18) (Fig. 3) or a Krueger flap (19) (Fig. 4), and is most beneficial on the inboard side of the pylon on a swept wing.



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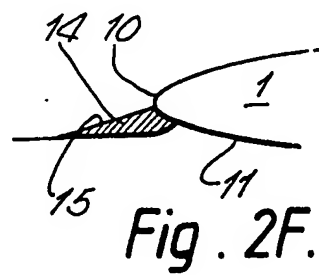
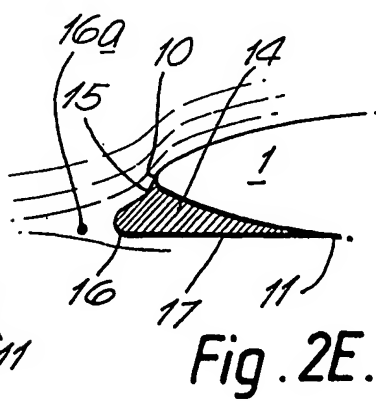
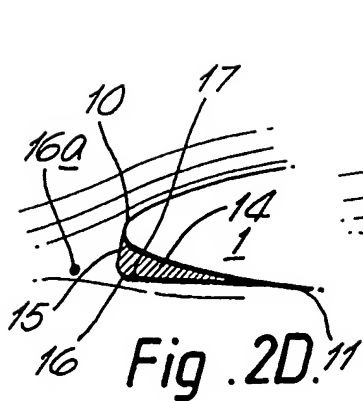
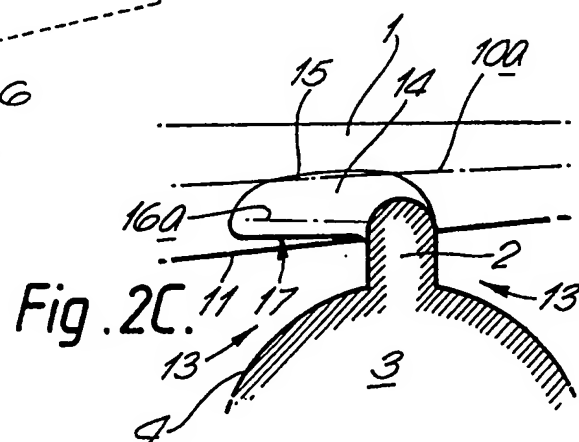
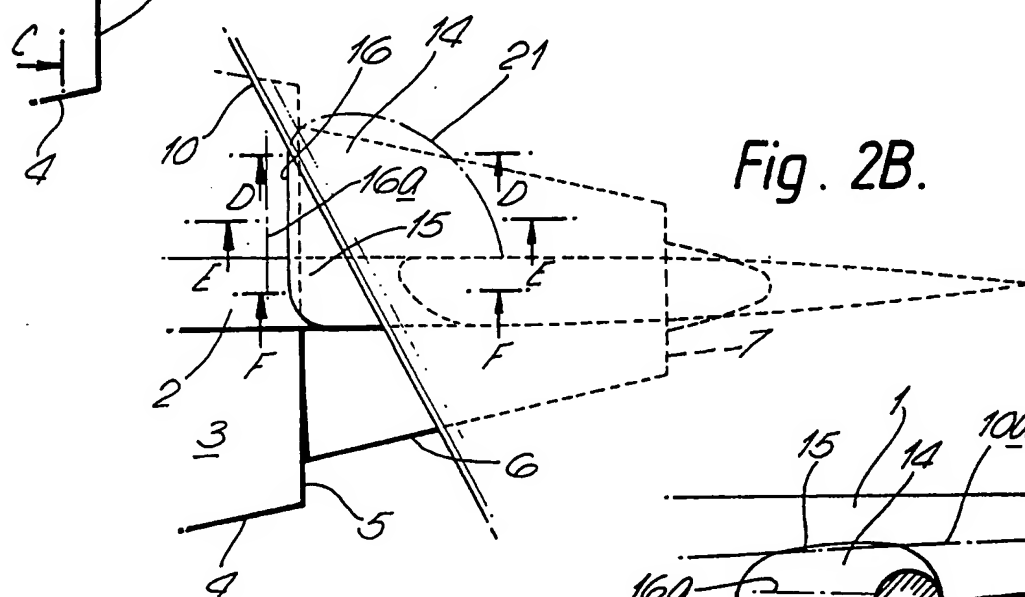
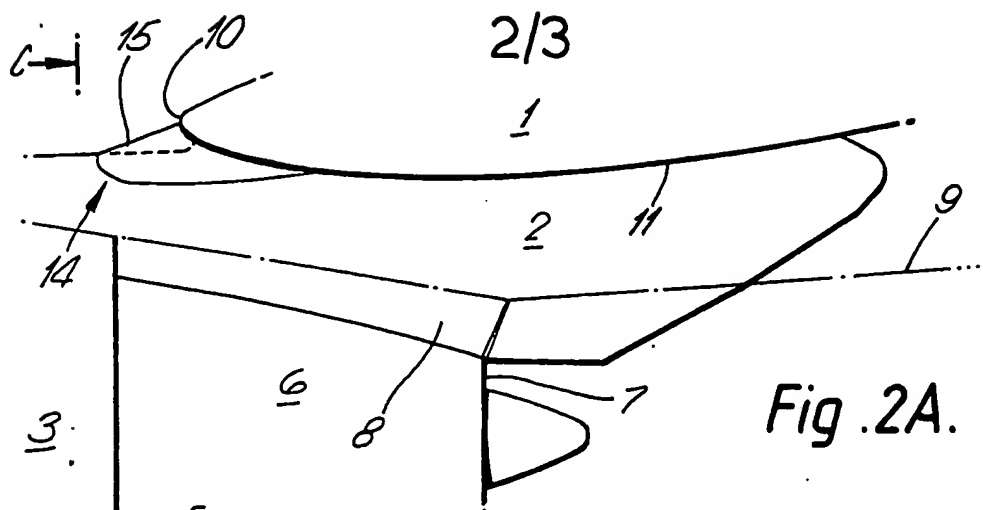


Fig. 3A.

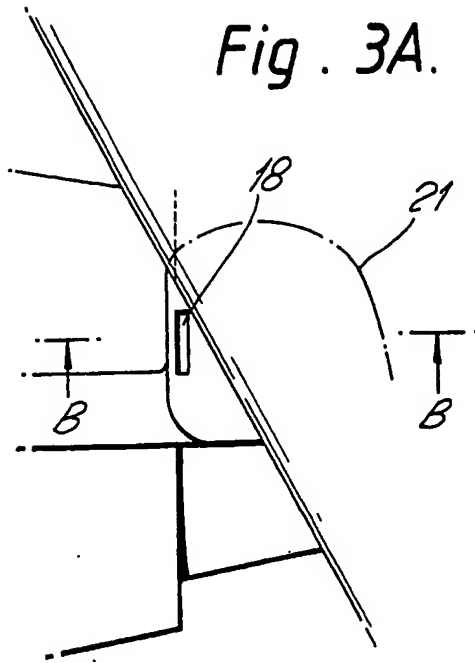


Fig. 3B.

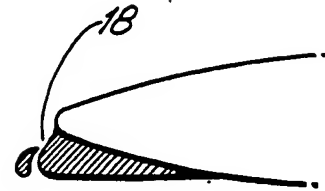


Fig. 4B.

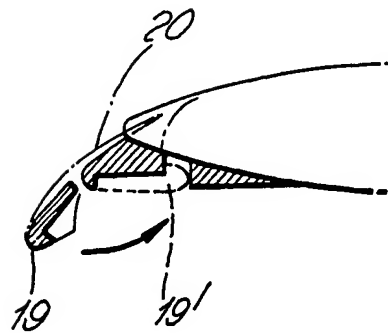
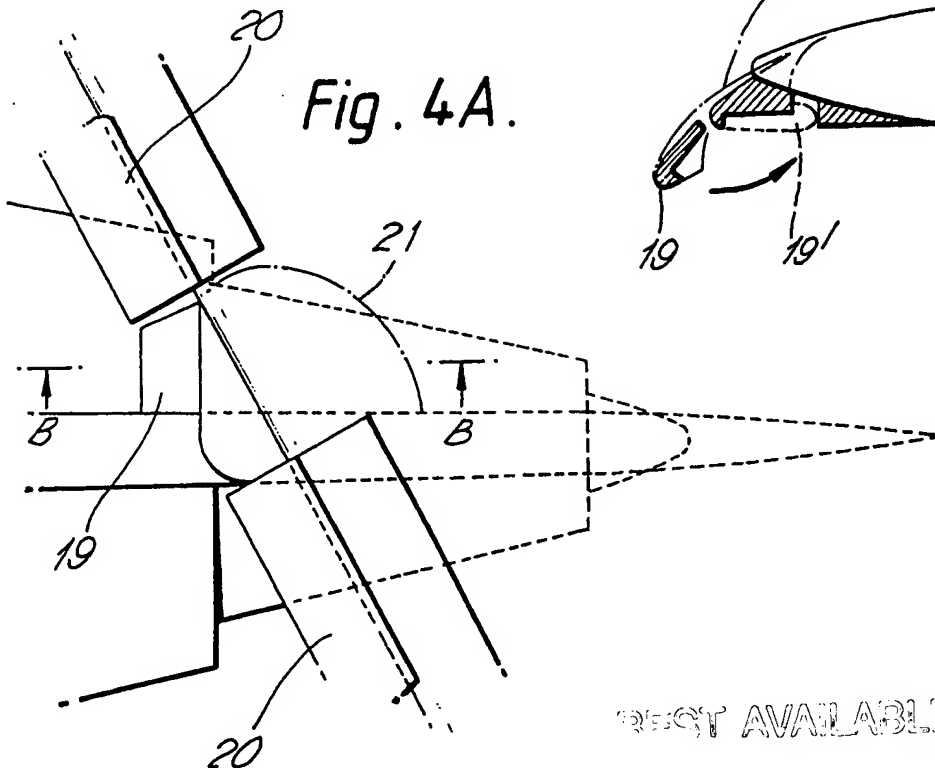


Fig. 4A.



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## SPECIFICATION

## Underwing engine installation for aircraft

5 This invention relates to aircraft having nacelles housing jet propulsion engines, which nacelles are carried by pylons depending from the wings of the aircraft.

With such arrangements, it is found that because 10 the pylons present a much narrower profile to the free airstream than the nacelle and the propulsive efflux therefrom, a channel region is formed by the juxtaposition of an undersurface region of the wing, a side region of the pylon, an upper region 15 of the nacelle and/or the boundary of the propulsive efflux, depending on where the nacelle is located with respect to the wing.

During flight, air from the free airstream is caused to flow through this channel. When the aircraft is at relatively high subsonic Mach numbers, 20 which may well be the case in cruising flight, this flow can experience sufficient acceleration to become supersonic with the undesirable drag producing corollary of shock wave formation and 25 possible separation of the flow from the channel surfaces.

An object of the present invention is therefore to so change the flow through the channel region that these undesirable effects are at least mitigated.

30 In this specification, the term "stagnation line" is defined as that line formed at or near a leading edge region of a body immersed in an airstream at which the airflow divides to flow on either side of that body.

35 According to the present invention, an aircraft having a wing, a nacelle housing a jet propulsion engine the efflux from which extends aft of the nacelle, and a pylon depending from the wing carrying the nacelle, an undersurface region of the 40 wing, a side surface region of the pylon, and an upper surface region of the nacelle and/or any efflux therefrom together forming a channel into which air from the free airstream is urged from a capture area bounded in part by stagnation lines 45 formed by said wing, pylon and nacelle, the wing, having, in the region of the channel, contour modifying means which form a new stagnation line positioned such that said capture area is reduced.

Preferably, the contour modifying means form a 50 stagnation line lower than that formed by adjacent spanwise regions of the wing when in the cruise condition.

Preferably, the contour modifying means form a wing undersurface region in said channel with little 55 or no chordwise curvature.

The contour modifying means may carry flow enhancing means such as flaps, slats or slots.

Some embodiments of the invention are described with reference to the accompanying drawings, in which: 60

*Figures 1A-C* comprise three views of a known underwing turbo-fan nacelle installation, Figure 1A being a side view, Figure 1B being a plan view, and, Figure 1C being an elevation,

65 *Figures 2A-F* comprise six views of a similar but

not identical installation with a contour modifying portion provided, Figure 2A being a side view, Figure 2B being a plan view, Figure 2C being a sectional view on line C-C of Figure 2A, Figure 2D 70 being a local sectional view on line D-D of Figure 2B, Figure 2E being a local sectional view on line E-E of Figure 2B, and, Figure 2F being a local sectional view on line F-F of Figure 2B,

*Figures 3A and B* are views of an alternative embodiment, Figure 3A being a plan view whilst Figure B is a sectional view upon line B-B of Figure 3A, and,

*Figures 4A and B* are views of yet a further embodiment, Figure 4A being a plan view and Figure 4B being a sectional view on line B-B of Figure 4A. 80

In *Figures 1A-C*, an aircraft has a wing 1, a pylon 2 extending generally downwards and forwards from the wing and carrying a nacelle 3 which houses a turbo-fan propulsion engine. Thus the nacelle comprises a fan cowl 4, with an annular fan efflux outlet 5 which exhausts around a rear portion of a cowl 6 housing the gas generating core of the engine. The gas generator exhausts at 7. 85

A typical shock wave formation 8 is illustrated in the fan efflux (*Figure 1A*) whilst the boundary between the fan efflux and the free airstream is shown at 9. At cruise conditions with free airstream Mach numbers typically between 0.65 and 0.85, the efflux from the fan outlet is partially or wholly supersonic and characterised by a series 95 shock/expansion cells. At or just downstream of the gas generator exhaust outlet 7, the fan efflux flow is processed by a relatively strong shock wave which turns the flow in a generally streamwise direction. 100

The wing 1 has a leading edge 10 from which the undersurface 11 of the wing extends rearwardly and convexly downwards before cusping towards the trailing edge 12. A stagnation line shown diagrammatically at 10a is formed when the flow divides to flow above and below the wing. Similar stagnation lines are formed by the pylon and the nacelle, but these are not shown. 105

As is particularly well illustrated in *Figure 1C*, channel regions 13 (shown hatched) are formed both inboard and outboard of the pylon 2, by the undersurface 11 of the wing, the outboard or inboard surface of the pylon 2 and, in this instance, the fan efflux boundary 9. Naturally, this boundary 9 may be replaced in other embodiments by upper surface region of the nacelle, depending upon the fore-and-aft location of the nacelle with reference to the wing. 110

The flow entering these channel regions 13 from the free stream, that is to say from a capture area bounded in part by the stagnation line 10a formed by the wing, the stagnation line formed by the pylon, and the stagnation line formed by the cowl 3, experiences acceleration and may become supersonic, causing a supersonic region in the flow terminating by a shock wave formation which for some combinations of Mach number and lift coefficient of the aircraft will lead to separation of flow both on the pylon and the wing. These supersonic effects are found to be less severe in the outboard 125 130

channel region due to the effect of wing sweep-back; accordingly in Figures 2A-F a contour modifying portion according to the invention is applied, by way of example only, to the inboard channel region. It is nevertheless applicable to either or both regions.

These supersonic effects become more severe as, for structural and other reasons such as ground clearance, the nacelles are mounted even more closely to the underside of the wing in the fore-and-aft and/or height senses.

Referring now to Figures 2A-F, in which similar nomenclature is used to that of the previous Figure and which illustrates an installation in which the nacelle is somewhat closer to the wing than in that Figure, a contour modifying portion 14 is provided inboard of the pylon 2.

This comprises an upper surface 15 extending from a region at or below the leading edge 10 of the wing to a new leading edge 16 lying forward and downward of the original leading edge 10, and an undersurface 17 extending rearwardly from the new leading edge 16 to the undersurface 11 of the wing. The undersurface 17 thus forms a revised undersurface for a leading portion of the wing; it is generally flat but it may have a slight convexity or it may be cusped, that is to say slightly concave. Irrespectively, it is a substantial area of little or no chordwise curvature. It thus removes a cause of acceleration of the flow in the channel region. The surfaces 15 and 17 and the new leading edge 16 extend inboard of the aircraft to blend with an inboard lower region of the wing, and they extend outboard to blend with an upper region of the pylon 2. The new leading edge 16 is substantially straight and unswept as illustrated, but it may be slightly swept or curved. In plan, the new leading edge 16 is close, although not necessarily coincident with the fan efflux outlet 5. When viewed from the front, the new leading edge 16 and the lower crest of the undersurface 17 are parallel to the fuselage horizontal datum plane rather than the wing leading edge 10. The portion 14 forms a stagnation line 16a downwards of that referenced 10a. That is to say, it is lower than the stagnation line formed by adjacent spanwise regions of the wing to the portion 14. This is when the wing is in the cruise condition with any high lift leading edge devices retracted.

Irrespectively of its other characteristics, the streamwise profile of the contour modifying portion is selected so as to avoid both substantial peak suction on the lower surface 17 which would interact adversely with the fan efflux flow and also result in adverse upper wing surface interaction. In some cases, it may be both desirable and possible to contour the upper surface 15 of the portion to fair into an upper surface of the wing, that is to say above the leading edge 10, to help remove any detrimental effect resulting from the presence of the pylon and nacelle.

In Figures 3A and 3B, a slot 18 is formed in the contour modifying portion.

In Figures 4A and B a Krueger flap 19 is fitted to the contour modifying portion. This Krueger flap is

movable from an extended position to a retracted position shown at 19'. Extended high lift devices on the existing wing are illustrated at 20.

In Figures 2B, 3A and 4A, the intersection line between the undersurface 17 of the contour modifying portion 14 and the undersurface 11 of the wing 1 is shown in broken outline at 21.

## CLAIMS

1. An aircraft having a wing, a nacelle housing a jet propulsion engine the efflux from which extends aft of the nacelle, and a pylon depending from the wing carrying the nacelle, an undersurface region of the wing, a side surface region of the pylon, and an upper surface region of the nacelle and/or any efflux therefrom together forming a channel into which air from the free airstream is urged from a capture area bounded in part by stagnation lines formed by said wing, pylon and nacelle, the wing having, in the region of the channel, contour modifying means which form a new stagnation line positioned such that said capture area is reduced.
2. An aircraft according to Claim 1, in which the contour modifying means form a stagnation line lower than that formed by adjacent spanwise regions of the wing in the cruise condition.
3. An aircraft according to Claim 2, wherein the contour modifying means for a wing undersurface region in said channel of little or no chordwise curvature.
4. An aircraft according to Claim 2, or Claim 3, in which the aircraft wing has a swept leading edge region and the contour modifying means has little or no sweepback.
5. An aircraft according to any one of Claims 2, 3 or 4, in which the contour modifying portion and the pylon locally blend with one another in the region of the channel.
6. An aircraft according to any of the previous Claims, wherein the contour modifying means carries flow enhancing means.
7. An aircraft according to Claim 6, wherein the flow enhancing means comprise slots, slats and/or flaps.
8. An aircraft substantially as described, with reference to Figure 2, Figure 3 or Figure 4 of the accompanying drawings.